May 1989 A Cahners Publication

R&D

Research & Development

Special Report:
The FSX controversy

Wafer cleaning
without surface damage

A most unusual
Lab of the Year

R&D

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***New equipment and techniques** for semiconductor research include high-vacuum process chambers (cover), photo-induced surface cleaning (page 74), and handling of toxic waste gases (page 107). Photo courtesy of Nor-Cal Products Co.*

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be a major sales contributor in 1990.

However, they will apply downward pricing pressure on the lower-performance processor-based equipment.

The 68040 and i486 triple the performance of their 68030 and 80386 predecessors and are expected to be used for applications that previously were performed on mainframes and supercomputers. The i860 is designed for high-speed multiprocessing systems and 3-D graphics. □

By 1992 EC technology will challenge the U.S.

IN LESS THAN 32 months the European Community's 12 countries and 320-million people officially become the second largest trading partner in the world. The EC's combined R&D also will take second place only to the U.S. in expenditures and talent.

That common R&D effort already is well under way. While such issues as banking and taxation will make the transition difficult, "the EC is set to function, particularly from a technological standpoint in 1992," says Catherine Morrison, director of public policy studies for the Conference Board, a New York business group.

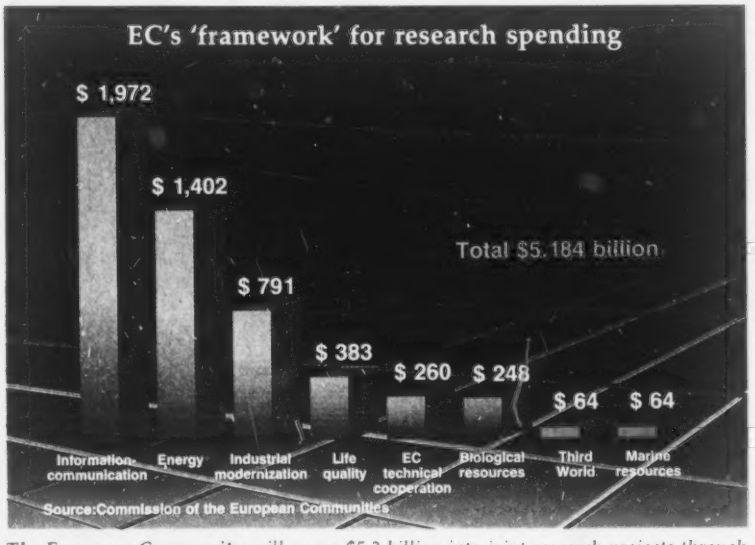
The EC's Framework Program for joint research and technological development has been in place for several years and has provided $5.2 billion in funding for the 1987-91 period. While this is a significant amount for community countries, it only accounts for 2% of all R&D activities in Europe, most of which is still national in nature.

Information technologies have the largest share (38%) of the allocations and promise to be the EC's dominant technology in the 1990s. Energy research (fission, fusion, nonnuclear, and nuclear safety, 27%) and industrial modernization (15%) also have high priority.

R&D for industrial competitiveness is managed within the Framework Program by such efforts as Esprit (information technology), RACE (advanced communications), Brite (industrial technology), and Euram (advanced materials).

The Framework Program is administered by the Council of Ministers, who recently expanded it with $610 million for industry and energy R&D programs for 1989 to 1992. The majority of this is follow-up funding for the Brite and Euram programs to support the EC's traditional manufacturing industries—automobiles, chemicals, textiles, and aircraft.

"Europeans currently view both the U.S. and Japan from a technological standpoint in the same manner as the U.S. now views the Japanese," says Morrison. The EC sees mergers, joint ventures, and alliances as the best way to be competitive, and has almost a 30% average annual increase in mergers and takeovers for the past five years.



***The European Community** will pump $5.2 billion into joint research projects through 1991. Another $610 million will go into industrial and energy R&D by 1992.*

The Japanese anticipate problems after 1992 in exporting to the EC. To circumvent this, they are establishing manufacturing facilities within the EC for internal sale and export to the U.S. and Japan.

The Japanese also are constructing R&D facilities within the EC to fully understand and relate to the local EC marketplace. □

Supply-side labor—the next competitive crisis

THE GROWTH OF science and engineering (S&E) jobs in industry is expected to increase 35 to 45% from current levels by the year 2000. This growth rate is lower than the 1977 to 1986 period due to slowdowns in available labor force, total employment, and GNP, according to a projection prepared by the National Science Foundation.

Even with a lower demand, the supply of S&E workers for these positions will be dramatically restricted by the availability of college graduates.

The college-age population is shrinking—by 1996 there will be 25% fewer people in this age group than there are now. The combination of these demographics and a lessening of interest in S&E careers is already responsible for a decline in the overall number of S&E degrees being awarded. In one UCLA study, the percentage of freshman opting for engineering declined from 12% in 1982 to 8.5% in 1987.

This overall decline could persist until the mid-1990s, says Univ. of Washington's dean of engineering, J. Ray Bowen.

The increase in demand and decrease in supply is further aggravated by increased pressure from R&D sectors for personnel with advanced degrees to maintain competitiveness with foreign companies.

Manpower requirements for the technical staffing of U.S. facilities in foreign countries, the staffing of foreign-owned R&D centers in the U.S., and an increase in S&E retirees further eats into the labor supply.

This problem can be alleviated by increasing the minority representation in S&E graduates, says Bowen. Currently, three fourths of S&E bachelor degrees are awarded to white males. Minority levels for BS candidates are 15% women, 3% black, 3% Hispanic, and 6% Asian. The percentages are even lower for advanced degrees, according to Engineering Manpower Commission reports. **R&D**

Keys to Top R&D Salaries: Age, Experience, Education

Sex differences remain in applied science salary picture, but at a lower level; industry-government-university trade-offs persist.

*By **Robert R. Jones**, Executive Editor, R&D magazine*

TO EARN the big salary in research and development, there is a simple formula: Be a 65-year-old male aeronautical engineer working in industry, with a PhD and 40 years' experience.

For the R&D scientist or engineer who may someday fit into the above formula, and even for those who won't, there is good news this year. Incomes in research and development are up, with an average real increase of 4% across all disciplines.

That, and other profile data about the R&D industry, including salary comparisons by disciplines and a discussion of the salary value of experience, were presented in the first part of this article (March, pages 44-47).

In this second part we will look at the salary benefits that apply to gender, amount of education, and workplace.

To begin with, 50% of the population is ruled out of the above high-salary formula by gender. Although its extent has been reduced in the past two decades, there still is sex discrimination in R&D salaries.

Along with that come factors which at first appear to be sex discrimination, but are merely sex/culture related. They lead to justifiable differences in men's and women's average salaries, but the women come out on the short end, none the less.

Women and work experience

One sex/culture-related factor is the job experience that was shown earlier to be so valuable. Women who follow spouses who move to new jobs or who delay or interrupt their careers to rear children rarely can accumulate 40 years' experience in R&D—but one of the things R&D pays for is experience.

Specifically, only 11.9% of the women responding to this survey have more than 25 years' experience in R&D, while 63.2% of the respondents earning more than $85,000 per year have more than 25 years' experience.

Also sex/culture related is the fact that a large portion of women scientists are in biology and a large portion of biologists are in universities.

The combination of female, university, and biology contrasts sharply with the male aeronautical engineer in industry. (Female, university, and mathematician or industrial engineer might be worse, but there are too few of them for our sample to identify.)

Even having a PhD in her field does not make enough salary difference to bring the female university biologist into the upper salary ranks.

Those higher degrees

The large figures that the R&D industry associates with PhD salaries got bigger during the past year. The median salary of PhD respondents to this survey increased by 7.8% to $54,351 from last year's $50,995. This amounts to an increase of more than 25% in five years.

The average R&D scientist or engineer with a doctoral degree now can expect a career advantage of $1,825,000 over his R&D colleague who did not go beyond the baccalaureate level.

The spread in average PhD over BS career earnings has nearly tripled in the past five years from $620,000 in 1984.

Respondents to this survey have made it clear that the net value of a PhD over a BS depends on an individual's field of endeavor and gender, and whether the employer is from industry, academia, or government.

When allowance is made for the fact that the above PhD benefits are based on the median for our respondents, it is easy to see that many PhDs will realize much larger benefits from their doctorates.

The $1,825,000 career benefit figure is what remains after we deduct costs of additional education and allow for the extra years spent in school.

We assume that the holder of the PhD will work 35 years after getting that degree, a figure that our survey shows is fully believable. We allow a 40-year career for the person who enters the work force after getting a BS.

Assuming an 8% interest rate prevailing over the 35-year career of the PhD and allowing $300,000 for tuition, missed earnings, etc., we then can make appropriate projections. From this, comes the PhD's career benefit figure.

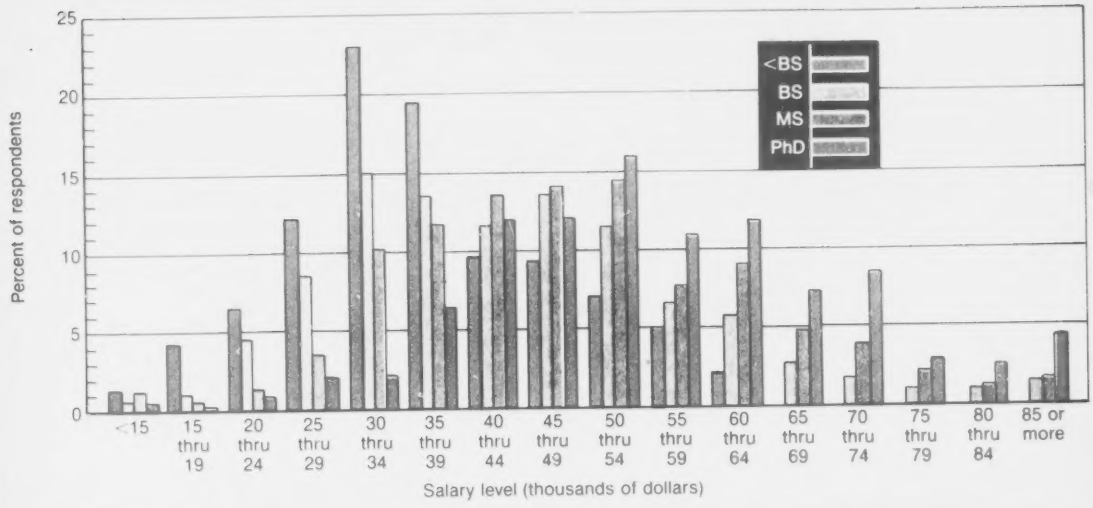
Using similar calculations with different allowances for earning years and expenses, we find that the present career value of a PhD over an MS is just under a million dollars, only a small change from last year's figure, but up from $370,000 five years ago.

Get that degree!

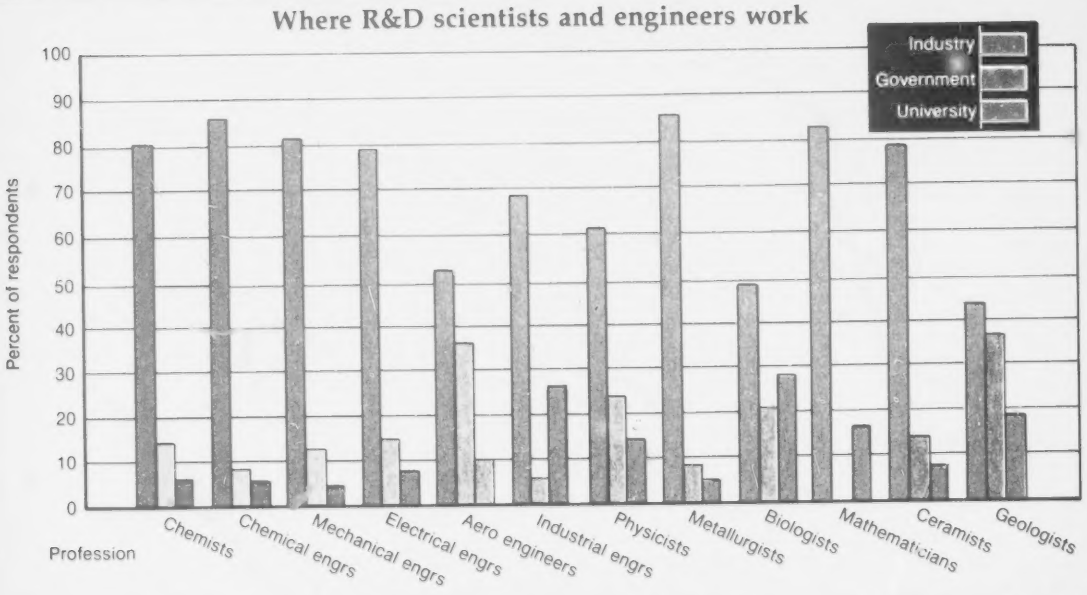
For this year's crop of new high school graduates who may be uncertain about the value of a college degree, the message in this survey is obvious: Get the degree.

Respondents report that the net ca-

How 1989 salaries reflect level of education



Where R&D scientists and engineers work



Median salaries by sex and workplace

	1989	1988	% change
Men in industry	$49,434	$45,111	+ 9.6
Men in government	45,802	42,667	+ 7.3
Men in universities	44,317	41,635	+ 6.4
Women in industry	36,561	35,543	+ 2.9
Women in government	41,249	33,500	+ 23.1
Women in universities	27,499	27,083	+ 1.5

Median salaries all R&D by workplace

	1989	1988	1987
Industry	$48,307	$44,175	$43,887
Government	45,482	41,786	42,200
University	43,181	40,250	38,621

Getting a PhD *vs* no college degree can be worth an added $3,030,000 over a 35-year career.

	1988 salary raise, amount						1989 salary range			Years with present employer		
	None (%)	Less than 2% (%)	2 thru 5% (%)	6 thru 9% (%)	10 thru 13% (%)	14% or more (%)	Median	<$15,000 (%)	>$85,000 (%)	Median	<1 (%)	>36 (%)
Aeronautical engineer	6.7	16.7	66.7	10.0	—	—	$57,500	—	3.3	17.00	—	—
Biologist	4.9	4.9	51.0	29.4	5.0	4.8	43,846	—	2.9	8.86	2.9	1.0
Ceramist	6.9	3.4	65.5	20.7	—	3.4	50,500	—	3.4	5.06	3.4	—
Chemical engineer	10.1	3.6	62.6	16.5	5.0	2.2	49,100	—	2.9	8.30	2.9	2.2
Chemist	9.4	3.9	54.7	21.9	6.6	3.5	45,243	0.3	2.0	8.84	3.0	0.5
Electrical engineer	11.7	6.2	51.2	22.8	4.9	2.5	50,185	1.9	2.5	10.63	1.9	—
Geologist	15.6	12.3	47.7	16.5	7.9	—	50,500	4.5	3.5	7.75	—	—
Industrial engineer	5.1	5.5	63.2	15.8	5.4	5.2	38,125	5.3	—	9.75	—	—
Mathematician	—	0.4	32.9	34.4	32.2	0.1	42,500	—	—	6.33	7.4	—
Mechanical engineer	9.9	4.2	50.2	25.4	8.5	1.9	48,900	0.5	0.9	8.46	3.8	0.9
Metallurgist	11.5	—	59.8	23.0	5.7	—	52,205	1.1	—	9.75	2.3	—
Physicist	6.0	11.9	56.7	21.6	3.0	0.7	51,087	—	—	9.67	6.0	—

1989 profile of the research and development industry

What is your annual salary?

Less than $15,000	0.8%
$15,000 to $19,999	0.9
$20,000 to $24,999	2.7
$25,000 to $29,999	5.6
$30,000 to $34,999	10.5
$35,000 to $39,999	11.3
$40,000 to $44,999	12.0
$45,000 to $49,999	12.8
$50,000 to $54,999	13.3
$55,000 to $59,999	7.9
$60,000 to $64,999	8.1
$65,000 to $69,999	4.4
$70,000 to $74,999	4.2
$75,000 to $79,999	1.8
$80,000 to $84,999	1.4
$85,000 or more	2.2

Your raise during the past year was

None	9.3%
Less than 2%	5.3
2 through 5%	54.8
6 through 9%	22.2
10 through 13%	5.6
14% or more	2.7

How long have you worked for your present employer?

Less than 1 year	3.5%
1 through 3 years	16.3
4 through 6 years	16.6
7 through 9 years	15.2
10 through 12 years	8.4
13 through 15 years	8.1
16 through 18 years	5.7
19 through 21 years	6.8
22 through 24 years	6.2
25 through 27 years	4.3
28 through 30 years	3.4
31 through 33 years	3.4
34 through 36 years	1.5
More than 36 years	0.6

What is your age?

Under 26 years	1.9%
26 through 30 years	9.5
31 through 35 years	14.1
36 through 40 years	16.3
41 through 45 years	15.6
46 through 50 years	13.3
51 through 55 years	11.5
56 through 60 years	11.2
61 through 65 years	4.2
Older than 65 years	1.9

How many years of experience do you have?

Less than 1 year	0.3%
1 through 5 years	11.6
6 through 10 years	15.6
11 through 15 years	16.5
16 through 20 years	14.8
21 through 25 years	12.7
26 through 30 years	11.7
31 through 35 years	9.8
36 through 40 years	5.1
More than 40 years	2.1

What is the highest degree you hold?

Less than bachelor	8.1%
Bachelor	35.2
Master	25.3
Doctorate	31.3

What is your profession?

Chemist	34.9%
Chemical engineer	8.1
Mechanical engineer	12.5
Electrical engineer	9.6
Aeronautical engineer	1.8
Industrial engineer	1.1
Physicist	7.8
Metallurgist	5.1
Biologist	6.0
Mathematician	0.4
Ceramist	1.7
Geologist	1.5
Other	9.5

Do you work in . . .

Industry	76.2%
Government	14.5
University	9.2

Are you . . .

Male . . 90.6% Female . . . 9.4%

Age, years			Experience, years			Highest academic degree			
Median	<26 (%)	>65 (%)	Median	<1 (%)	>40 (%)	<BS (%)	BS (%)	MS (%)	PhD (%)
47.14	—	13.3	27.00	—	16.7	—	51.0	36.7	12.3
40.25	—	—	15.12	1.0	—	2.0	12.7	24.5	59.8
37.81	—	—	14.58	—	—	3.4	13.8	42.6	40.2
40.19	1.4	2.2	14.33	—	2.2	1.4	42.4	31.7	24.5
42.56	1.0	1.3	16.87	0.2	1.3	4.4	37.2	19.5	38.9
43.91	2.8	3.4	20.71	—	2.5	14.8	43.8	31.5	9.9
46.50	—	4.0	18.75	—	4.2	—	19.1	36.7	44.2
48.12	—	—	20.50	—	—	31.6	21.1	32.4	14.9
40.10	—	—	8.33	—	—	—	48.7	17.9	33.4
41.46	4.2	1.9	16.54	0.9	2.3	12.7	43.7	31.5	12.2
44.77	2.1	2.5	19.79	—	1.1	6.9	40.2	21.8	31.0
45.21	2.2	1.5	18.86	0.7	1.5	0.7	22.4	26.1	50.7

reer benefit for a BS over less-than-BS is $1.2 million.

Entirely separate from the personal benefits that accompany a bachelor degree, the extra two, three, or four years that might be necessary to go from less-than-BS to having the diploma would return to a typical individual a minimum of $300,000 per year invested.

Adding the MS to a BS is worth another $825,000 over a career, or roughly $23,000 additional income in each year of the career.

There are other interesting and helpful comparisons that can be drawn from this survey of salaries in relation to the highest academic degree as you will see in the accompanying table.

As has been true in recent years, the income advantages of baccalaureate and advanced degrees again increased as fast or faster than the rate of inflation. However, the median income for respondents with less than BS did not keep up with inflation.

One result of this situation is that the median advantage of a PhD over less-than-BS in annual income increased to $18,704. Thus the career income benefit for the individual with a PhD degree over the one with no degree rises to an astounding $3,030,000, or nearly $86,000 for each year of the career.

The career difference for PhD over no degree has increased by more than 20% in just two years, having been $2,480,000 in the 1987 survey.

Who has the degrees?

Advanced degrees are much more common in some disciplines than in others. Biologists lead the R&D industry in PhDs with 59.8%, up from 56.0% last year and 52.0% in 1987.

Physicists rank second with PhDs among this year's respondents at 50.7%, up from 49.0% last year; geologists are third with 44.0%, down from 51.5% last year; and ceramists are 4th-high at 41.4%, unchanged from last year.

Electrical engineers report the fewest PhDs, with 9.9%.

Looking at total advanced degrees, masters plus PhDs by disciplines, biologists retain their leadership with 84.3%, an increase from 72.5% last year; ceramists are second at 82.8%, having had 69.0% last year; and geologists, at 80.0%, are down from 84.8% last year.

Electrical engineers count the fewest advanced degrees with 41.4%. Next-low are the mechanical engineers at 43.7%.

As a final comment about numbers of advanced degrees, it should be mentioned that last year's report pointed to the fact that "for some reason, possibly because of early retirement programs, the portion of respondents with PhD degrees in our annual survey has been declining in recent years."

After climbing to 33.1% in 1985, the PhD portion dropped to 30.1% in 1986 and 28% in 1987. The number moved very little last year, rising only to 29.2%. For this year's respondents, however, the figure stands at 31.3%, close to where it had been in earlier years.

Those who earn less

Reference was made earlier to the fact that these are all median figures, and that many PhDs will earn substantially more than the figures cited. By the same token, there will be some who earn substantially less, and a large portion of these will be women.

This result can be seen in the table showing salary by sex and workplace. Also notable in that table is the large increase in median salary this year for women who work in government.

In 1985, the median annual income for women working in government research and development was higher than the figure for women in industry. The median for this group fell in 1986, remained level in 1987, and by last year had returned to the 1985 level.

With this year's results, the salaries of women who work in government R&D again are ahead of those in industry. However, as the table clearly shows, the highest median salary for women in R&D (in government) remains below the lowest median for men (in universities). The difference is more than 7%.

Eventually, that may change. Over a number of years this annual survey has shown that women are doing a little better than men do when it comes time for salary increases.

From the last table in this article it can be shown that 40.7% of women respondents received salary increases last year that were equal to or higher than the rate of inflation. Only 29.7% of the men did as well.

The corresponding figure for women last year was 35.6%.

Job longevity

For many years, it was safe to say that nothing helps a person move up the corporate ladder in R&D like being with one organization for a long time.

While this is akin to years of experi-

In a year of change, many R&D industry trends have wavered or turned in new directions.

R&D salaries compared by academic degrees

Degree	Median salary 1989	Median salary 1988	Percent change	Annual difference* 1989	Annual difference* 1988	Difference change (percent)
Doctorate	$54,351	$50,955	+7.8	$6,436	$6,350	+ 1.3
Master	47,915	44,605	+7.4	4,982	5,537	−10.1
Bachelor	42,933	39,068	+9.9	7,286	4,837	+50.6
<Bachelor	35,647	34,231	+4.1			

*Difference above next lower degree

Percent receiving R&D salary increases by sex

Amount of increase	Granted in 1988 Male	Granted in 1988 Female	Granted in 1987 Male	Granted in 1987 Female
None	10.0	3.1	14.5	14.1
Less than 2%	5.3	5.6	6.6	4.0
2 through 5%	54.9	50.6	50.1	46.3
6 through 9%	21.4	31.9	21.3	24.9
10 through 13%	5.7	4.5	4.6	6.2
14% or more	2.6	4.3	2.9	4.5

ence, in some organizations it seemed to be even more important. The chart of salary for years with present employer rose as consistently with the passage of time as did the chart of salary for experience.

Now things have changed. There are new companies marketing new products in new ways. Mergers and acquisitions have blurred old seniority patterns and company loyalties.

No longer is it advantageous merely to have stayed with the same company for 15 or 20 years. That is, longevity is not a salary asset in and of itself.

This can be seen in the data from those respondents reporting salaries of $50,000 per year or more in this year's survey.

Dividing those respondents into two groups, those who have been with their present employer less than 10 years and those who have worked for the same employer between 10 and 20 years reveals that 55% had been with their present employer less than 10 years and only 45% are in the higher longevity group.

Men working in research and development are more likely to fill the traditional longevity role than are women, and reasons for this have been mentioned.

Among this survey's respondents, 23.6% of the men have worked for the same employer more than 18 years, compared to only 13.2% of the women being with the same employer more than 18 years.

Detailed comparisons for research and development workers by their disciplines are made in the large table accompanying this article. It shows range and median for four categories of information and percent distribution for two other catagories for each discipline.

Complete results of this year's Profile of the Industry survey are shown in the other large table.

Reversing the trends

It should be noted that last year's Profile of the Industry pointed to what seemed at the time to be a significant number of downward trends in important parameters. These were slippages which, it was suggested, could presage serious problems for the R&D industry.

One is almost tempted to ask whether mentioning those trends was all that was needed to reverse them.

Be that as it may—without exception—every trend which was cited as a possible cause for concern last year has been reversed this year.

One cause for concern was the possibility that the R&D work force was losing its experienced workers and they were being replaced with entry-level workers.

This concern was fostered by these developments:

- The portion of respondents with less than one year's experience had increased steadily to 0.6% last year. (It fell to 0.3% this year.)
- The portion with less than 6 years' experience had climbed to 12%. (It fell to 11.9%.)
- At the same time, the portion of respondents with more than 35 years' experience had declined by more than a fifth, from 6.8% to 5.4%. (It hit 7.2% this year.)
- As regards time with present employer, the portion with fewer than 4 years had risen dramatically by a sixth in three years to 21.0%. (It dropped even more dramatically to 16.3% this year.)
- Another clue to a younger and inexperienced work force was the fact that the portion of respondents earning less than $25,000 per year had moved resolutely to 7.7%. (It now is at 4.4%.)
- Respondents who were younger than 31 years of age had increased until the portion hit 13.2% last year. (Now 11.4%.)
- And the final cause for concern was the fact that the median salary for all R&D workers had been increasing at a decreasing rate of 6.3%, 3.2%, 4.3%, and 0.42% in succeeding years. A dip into the negative seemed almost certain.

However, it didn't happen. As has been mentioned earlier, this year's survey revealed the largest median salary increase for R&D in a number of years, 9.25%.

The listing of these causes for concern in last year's report was followed by the statement, "Most of the above changes are small, hardly worthy of mention by themselves, but when there are so many changes happening at the same time it is hard to say that they hold no significance."

Now it can be said: They held no significance. R&D

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